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I/O Box commissioning on Trimble Groundworks machine control system for drilling rigs

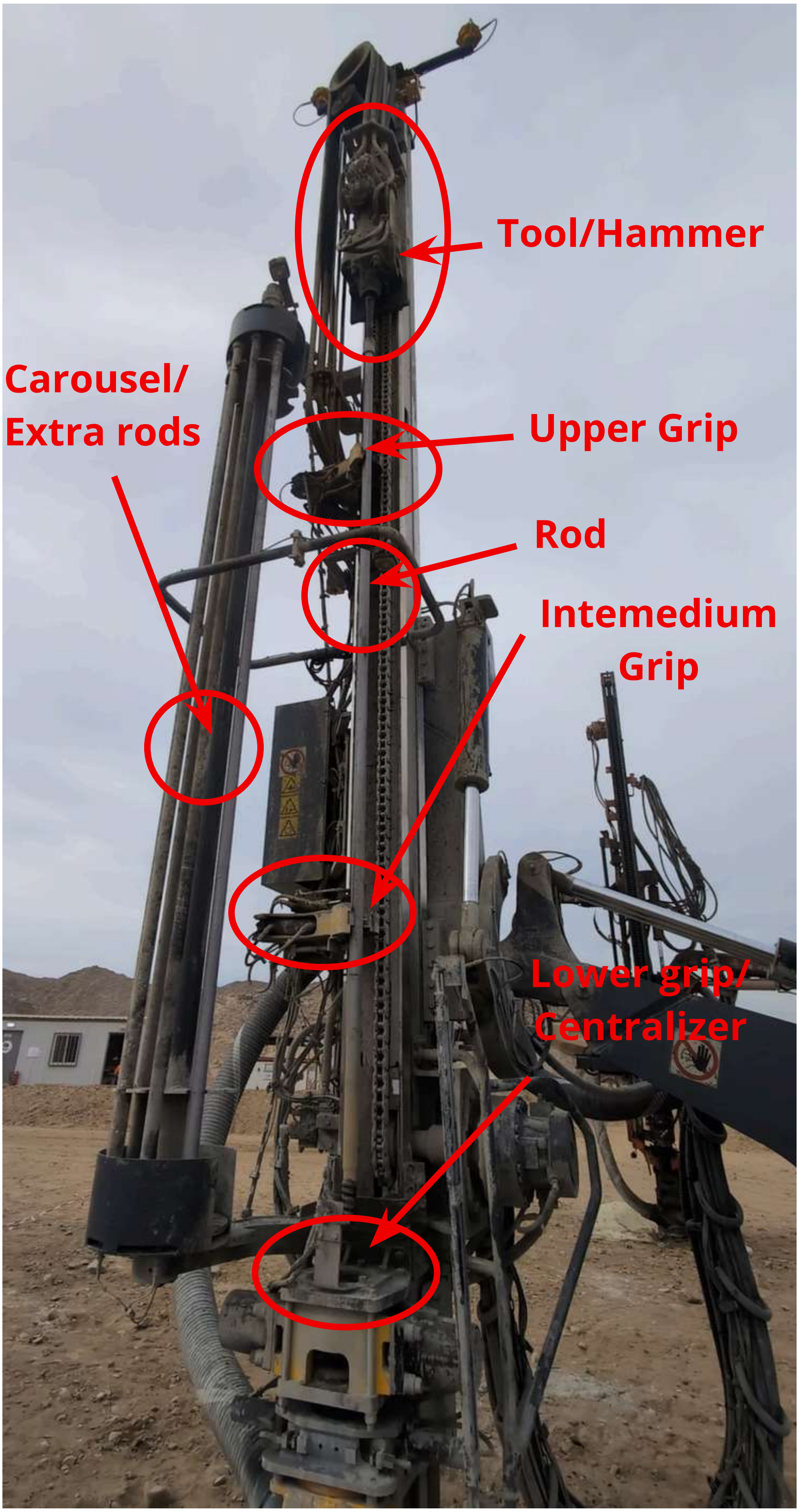
What is the I/O box?

I/O box stands for "Inputs and Outputs box" and it is an electric board that allows to read machine signals and to perform machine actions by signals delivered by Trimble Groundworks machine control system when required. It can be installed in both piling and drilling rigs with usually different purposes in each case. This document focuses on drilling application, although similar principles would apply for piling rigs.

Describing a drilling rig functioning

A drill rig is structurally similar to a hydraulic excavator, but the standard boom and stick assembly is replaced by a long vertical mast. The mounting configuration of this mast varies depending on manufacturer and model. Moving vertically along the mast is a rotary head that provides clockwise and counterclockwise rotation, while simultaneously channeling compressed air through its hollow spindle. This head connects to a hollow drill rod, which is threaded at the bottom to a drill bit – the component in direct contact with the ground.

The drilling mechanism operates on principles similar to a standard household hammer drill. Lowering the rotary head applies downward force (feed) onto the drill string. Simultaneously, the rotation of the drill bit grinds and shears the rock or soil face. An impact mechanism generates high-frequency axial percussive waves that travel down the rod, creating a hammering effect that fractures the material ahead of the bit. Finally, compressed air (flushing) is forced down through the hollow rod and exits at the bit, blowing the cuttings up the borehole to the surface. This continuous evacuation clears the hole and prevents unproductive friction, maximizing penetration efficiency.


Tool/Hammer
Carousel/
Extra rods
Upper Grip
Rod
Intemedium
Grip
Lower grip/
Centralizer

Aside from large-diameter foundation machines (such as Continuous Flight Auger rigs), most drilling rigs are designed to drill deeper than the length of a single drill rod. To achieve the required target depth, multiple rods must be added sequentially to the drill string. A mast-mounted rod changer carousel (or magazine) holds the spare rods needed for the operation.

To add the first rod, the carousel pivots laterally to align a rod with the rotary head's spindle axis. Hydraulic break-out clamps grip the rod to prevent it from rotating during the threading of the tool or slipping down the hole. The rotary head then moves down and spins clockwise to thread into the top of the new rod. Once the connections are tightly torqued, the clamps release, and the carousel retracts to its standby position. For the initial setup, the rotary head lowers the first rod through the lower clamp, which engages to secure the rod. This allows the operator to manually thread the drill bit onto the bottom tip. Before drilling commences, the lower clamp is slightly opened. It remains closed enough to act as a centralizer, ensuring the drill rod stays perfectly aligned with the intended borehole path.

Bottom grip / Centralizer

Drill Bit

The drilling process then executes as described in the first section, continuing until the rotary head reaches the bottom of its travel and meets the centralizer, signaling that the maximum feed stroke has been reached. At this point, the centralizer tightly engages to act as a lower clamp, securing the drill string to prevent it from rotating during unthreading or slipping down into the borehole.

The rotary head then spins counterclockwise while hoisting upward to unthread from the spent rod, clearing space for a fresh one. Next, the rod changer carousel indexes to align a new rod with the drill string axis. The loading process repeats, with the only difference being that the bottom of the new rod is now threaded into the top of the previously drilled rod, which remains locked in place by the lower clamp. Once the upper connections are torqued, the clamps release back to their guiding position, and drilling resumes.

Why is an I/O box needed?

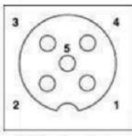
The drilled depth on a rig is generally measured using either a rotary encoder or a proximity switch pulse box integrated with the feed system – typically the winch drum, wire rope, or feed chain. As the feed mechanism moves, the sensor rotates. By establishing a fixed ratio between sensor rotation and linear travel, the system precisely tracks the vertical movement of the rotary head.

However, tracking actual drilling depth is challenging due to the multi-rod workflow. There are several phases where the rotary head moves without advancing the borehole. To ensure accuracy, the depth counter must selectively pause. For example, when the rotary head retracts upward to load a new rod, this upward travel must not be subtracted from the total depth. Once the new rod is added and the bit returns to the bottom of the hole, the system must automatically resume counting, adding only the newly penetrated distance to the total hole depth. To achieve this, Groundworks must monitor real-time machine signals to accurately identify the active operational phase. This allows the system to precisely pause depth tracking during non-drilling activities and resume it when penetration restarts, ensuring total data accuracy and integrity.

The I/O Box also enables a feature commonly known as “auto-stop,” which prevents the rig from drilling beyond the project's target design elevation. When the Groundworks system detects that the borehole has reached its specified target depth, it triggers an output signal that de-energizes the machine's feed-down circuit, instantly halting downward progress and eliminating accidental over-drilling. If operational requirements require the operator to override this function, they simply need to hoist the rotary head slightly and re-engage the downward feed, which temporarily deactivates the auto-stop restriction.

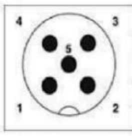
Installation schematics

There are 6 input ports on the I/O Box, labeled as IN, consistent of M12 5 pins female connectors and 2 output ports, labeled as OUT, consistent on M12 5 Pins male connectors. The other 2 M12 ports are the CAN ports to connect the box to the rest of the CAN line on serial, on the same way as we do with any other CAN sensor on the system.



pin - 1	10..30V DC (Supply voltage)
pin - 2	Active low input (Yellow Led)
pin - 3	GND
pin - 4	Active high input (Green Led)
pin - 5	Not Connected

Digital Input 1-6



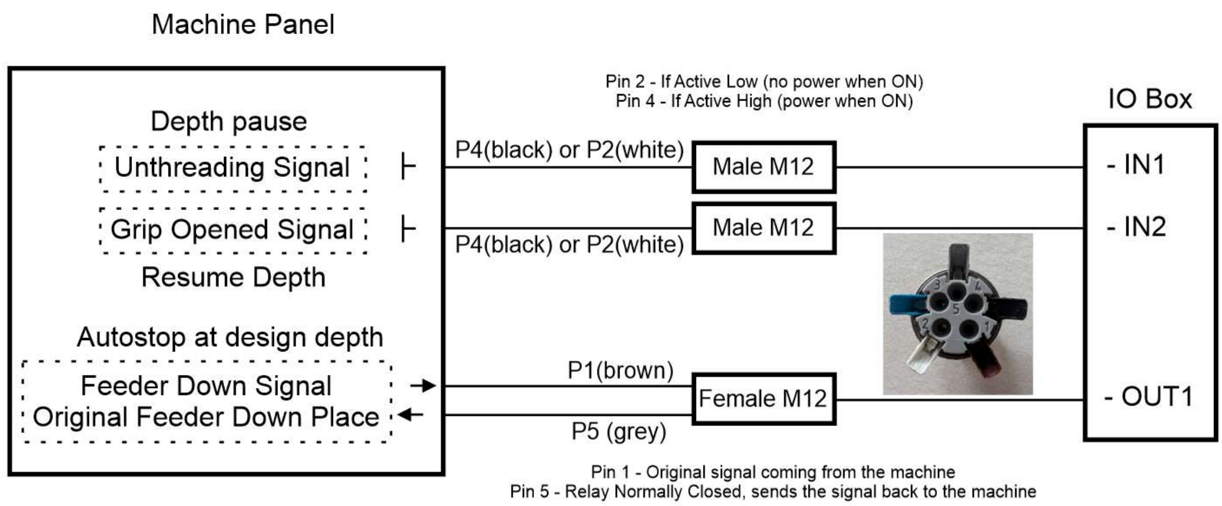
pin - 1	COM
pin - 2	Not Connected
pin - 3	Not Connected
pin - 4	NO
pin - 5	NC

Output Relay 1-2

The input signals can be connected as “active low”, meaning that if the function is ON at the machine, there is no power running through the control wire – the above led will light up on yellow then; or “active high”, what is more common in many machines, and means that the signal cable for the function will have power when the function is active on the machine – the above led with light up in green then. If we are on the first case, the signal cable will be connected to the pin 2 (white) of the input port and when the condition is met; if we are on the second, then it will be connected to the pin 4 (black).

Identifying the correct machine signals requires a qualified machine technician or system expert. Because these rigs demand a high level of maintenance, many fleet owners employ an in-house electrician who can assist with this process. If internal electrical support is unavailable, the necessary signal routing can be determined by auditing the machine's electrical schematics or by contacting the original equipment manufacturer (OEM). This manufacturer support can be facilitated either through the customer's technical point of contact or via the Trimble OEM team.

Input signals must be tapped in parallel, meaning existing cables should remain fully seated in their sockets – simply connect an extra cable to the active signal line socket. Conversely, the feed-down output signal from the machine must be completely cut to run inline through our system. The cleanest way is disconnecting the signal from the machine socket and connecting the machine-side source wire to P1 (Brown) and connect P5 (Grey) to a wire connecting to the original signal socket at the machine. That way, all the wires in the original machine harness are left intact and the system can be disconnected, ensuring that machine integrity as before adding anything to it.



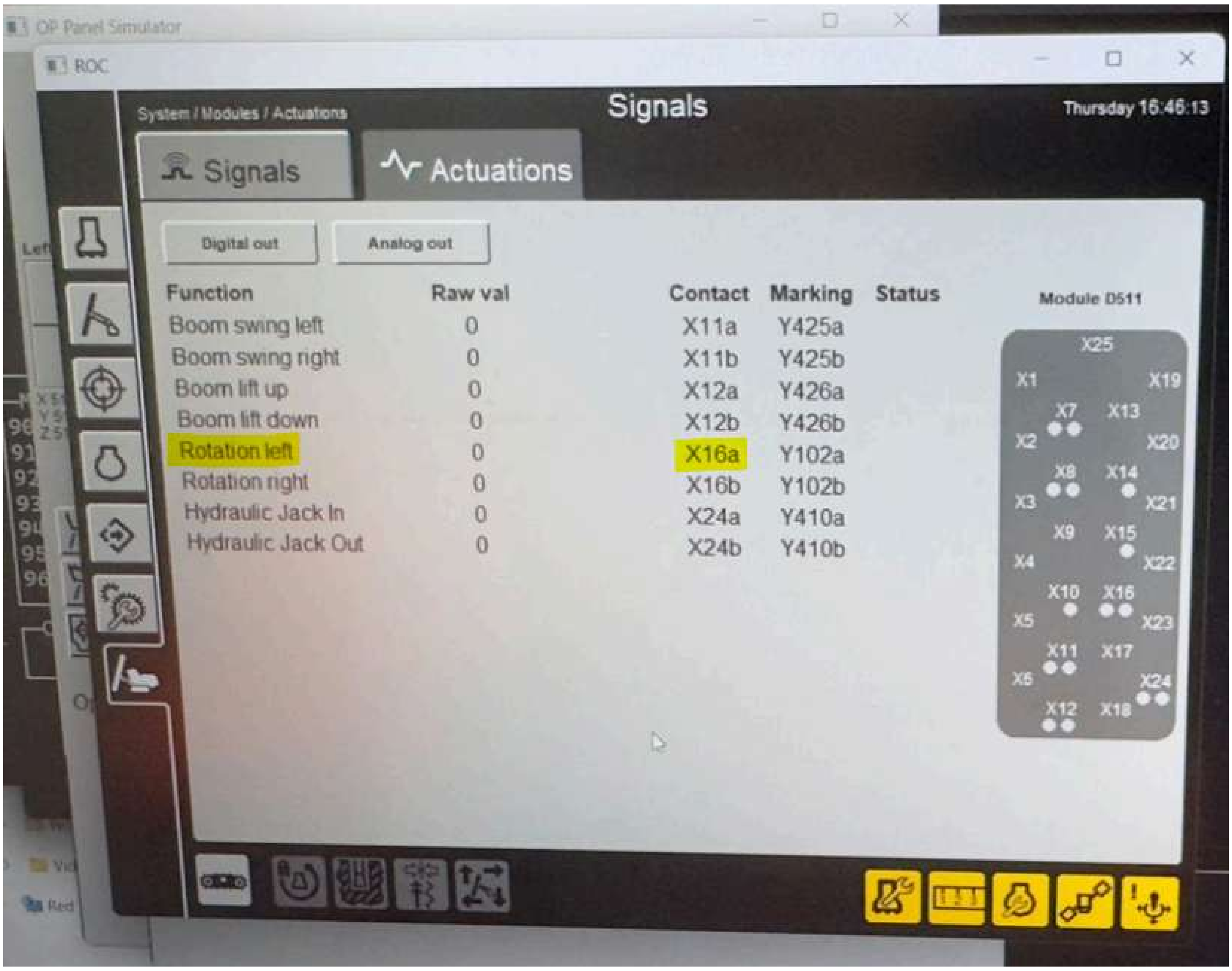
Connecting the inputs on an Epiroc D65

The primary sequence to monitor during operation is the rod-addition sequence. As explained before, this occurs when the initial drill rod has reached its maximum depth, requiring an additional rod to continue drilling. During this process, the rotary head retracts upward to accommodate the new rod. This upward travel must not be subtracted from the total hole depth. To prevent this, depth tracking must be paused the moment the rod change initiates by monitoring the machine signals that define this specific operational phase.

Looking at the mechanical sequence, the lower clamp closes first, securing the embedded drill string to prevent rotation. The operator then reverses rotation to unthread the rotary head from the rod. This unthreading signal is the ideal trigger to pause depth tracking, as it is uniquely activated during a rod change. As the rotary head hoists upward to clear space for the new rod, the sensor's travel data is ignored by the depth accumulator. A new rod is then indexed from the carousel, aligned with the drill string axis, greased, and threaded into both the rotary head at the top and the stationary drill string at the bottom. Once this process is complete, the lower clamp opens – a signal that safely triggers the system to resume depth tracking.

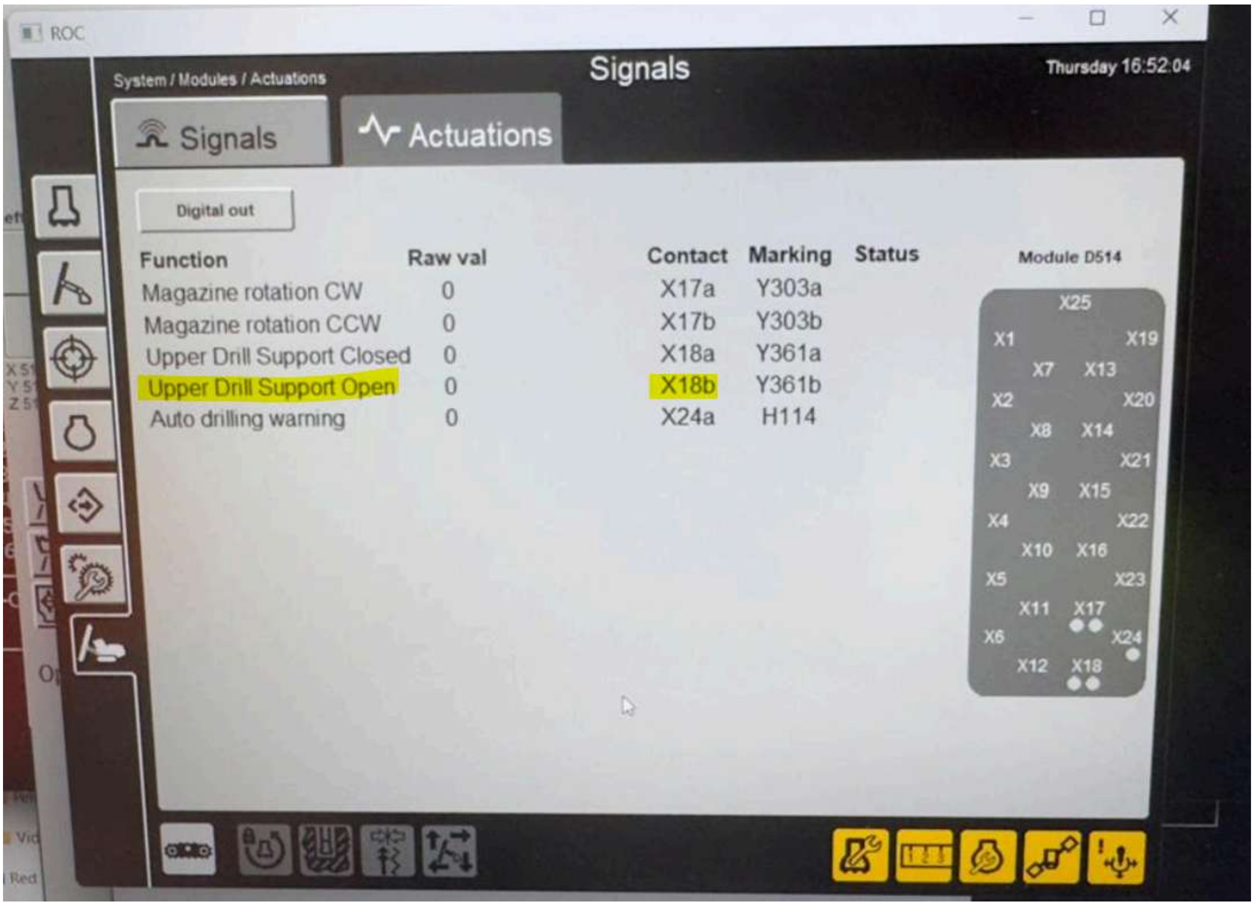
Note that the clamp-closure signal itself cannot be used to pause tracking because the lower clamp serves a dual function: it clamps tightly to thread/unthread rods, but it also closes partially during active drilling to act as a centralizer, preventing drill string deviation. Therefore, to ensure data integrity, the unthreading signal must be used to pause the depth tracking logic. According to the machine manual, this signal is called by Epiroc "Rotation Left" and it is located on terminal port X16a of the Module D511, as shown on the underneath image.

Note that different brands refer to the same action with different names, so having basic technical understanding of the electronics of the machine results is very helpful on site.



Unthreading signal – X16a of D511 Module

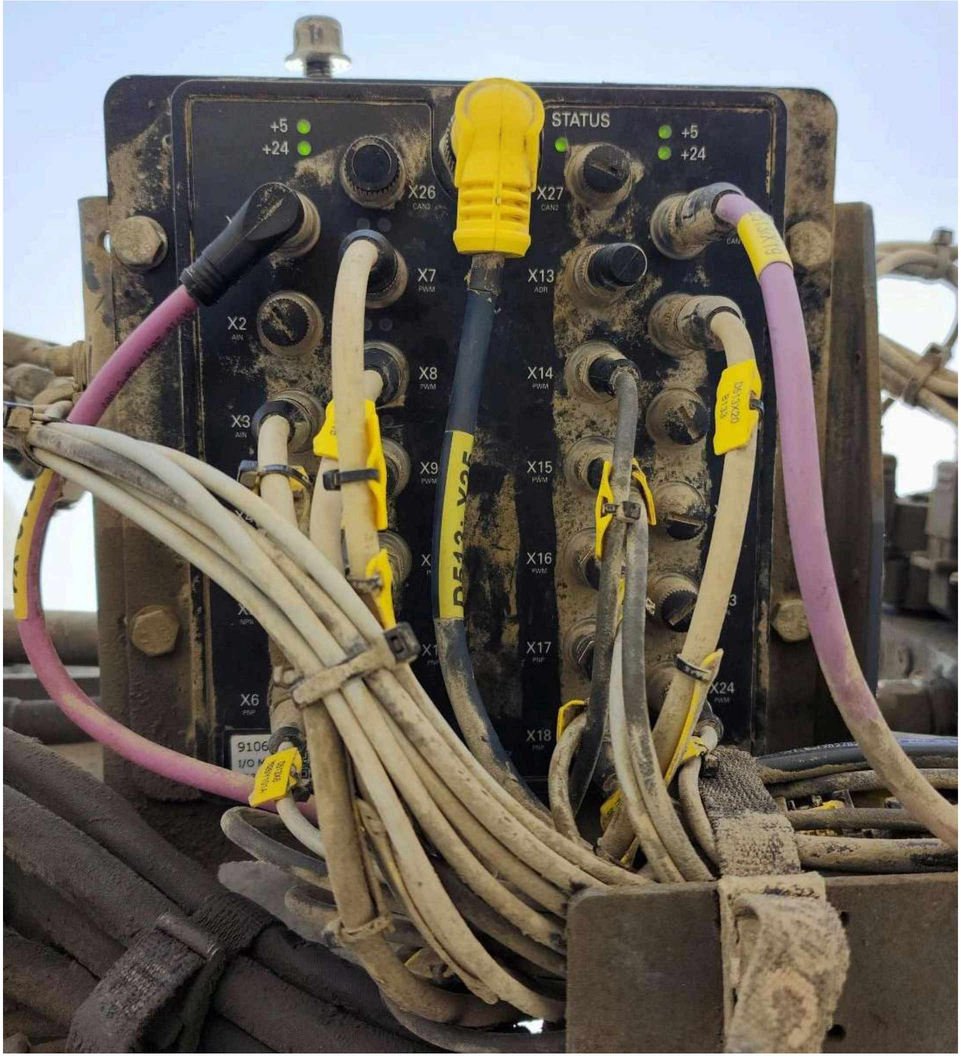
The last action occurring just before resuming the drilling operation is that the lower grip opens to its centralizer position, which is an ideal trigger to restore the depth count on the system. This signal is called by Epiroc as "Upper Drill Support Open" and located on the port X18b of the module D514, as shown on the manual screenshot ahead.



Lower grip/Centralizer open signal – X18b of D514 Module

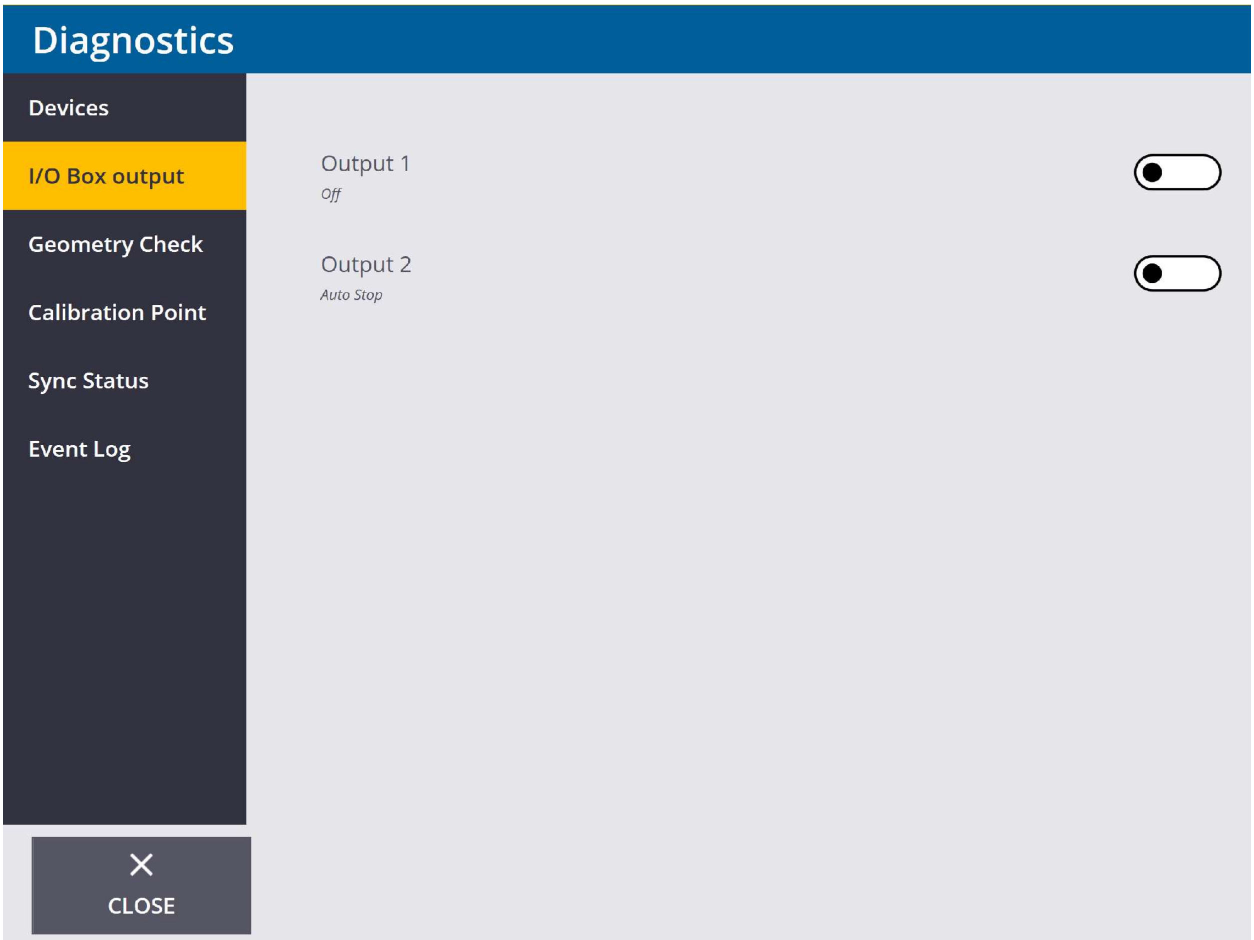
The machine module information contains a graphic to explain where these electrical modules are located on the machine.

They look like an electric panel with multiple M12 ports labeled as in the manual, same as the one shown on the underneath image.

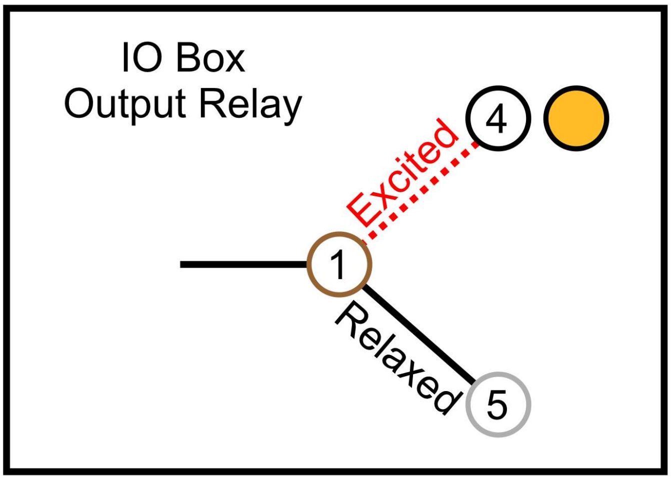


Connecting the outputs on an Epiroc D65

The system outputs allow Groundworks to interact directly with the machine's physical hardware. These outputs function as dry-contact relays, providing standard configuration options for both Normally Closed (NC) circuits – which open when triggered – and Normally Open (NO) circuits, which close when energized. To verify physical wiring and functionality, these output relays can be manually forced and tested via the Trimble Groundworks diagnostics page.



When triggered, the specific relay gets excited, so the IO box flips the switch that is connecting Pin 1 (brown) to Pin 5 (grey) to connect Pin 1 (brown) and Pin 4 (black), showing a yellow light on the physical unit to indicate that the relay is excited.

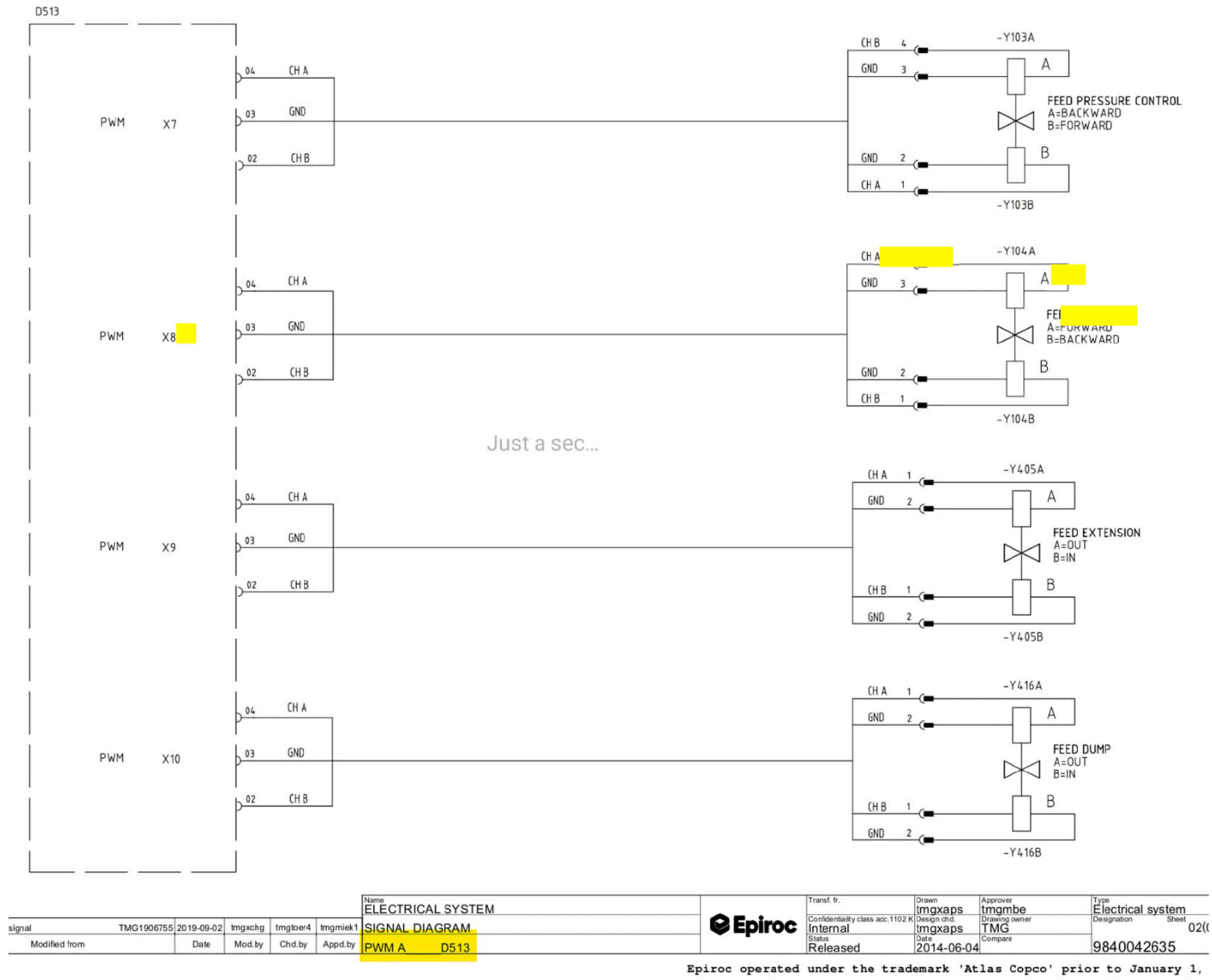


This is exactly what the auto-stop signal does when GW identifies that the operator has reached the project depth.

To verify proper output functionality, a continuity test can be performed across the hardware pins. With the output in its default, un-triggered state, continuity should be present between Pin 1 (Brown) and Pin 5 (Grey). Navigating to the diagnostics menu of the I/O Box within Groundworks and activating the designated output (labeled as Output 1) should break this initial connection. Upon activation, continuity should shift, clearing the connection between Pin 1 and Pin 5, and establishing a new connection between Pin 1 (Brown) and Pin 4 (Black). Successful circuit switching confirms that the I/O Box is operating correctly, which is further indicated by an illuminated yellow status LED on the physical output channel. As shown in the reference diagram, when both outputs are actively triggered, both corresponding internal relays are energized.

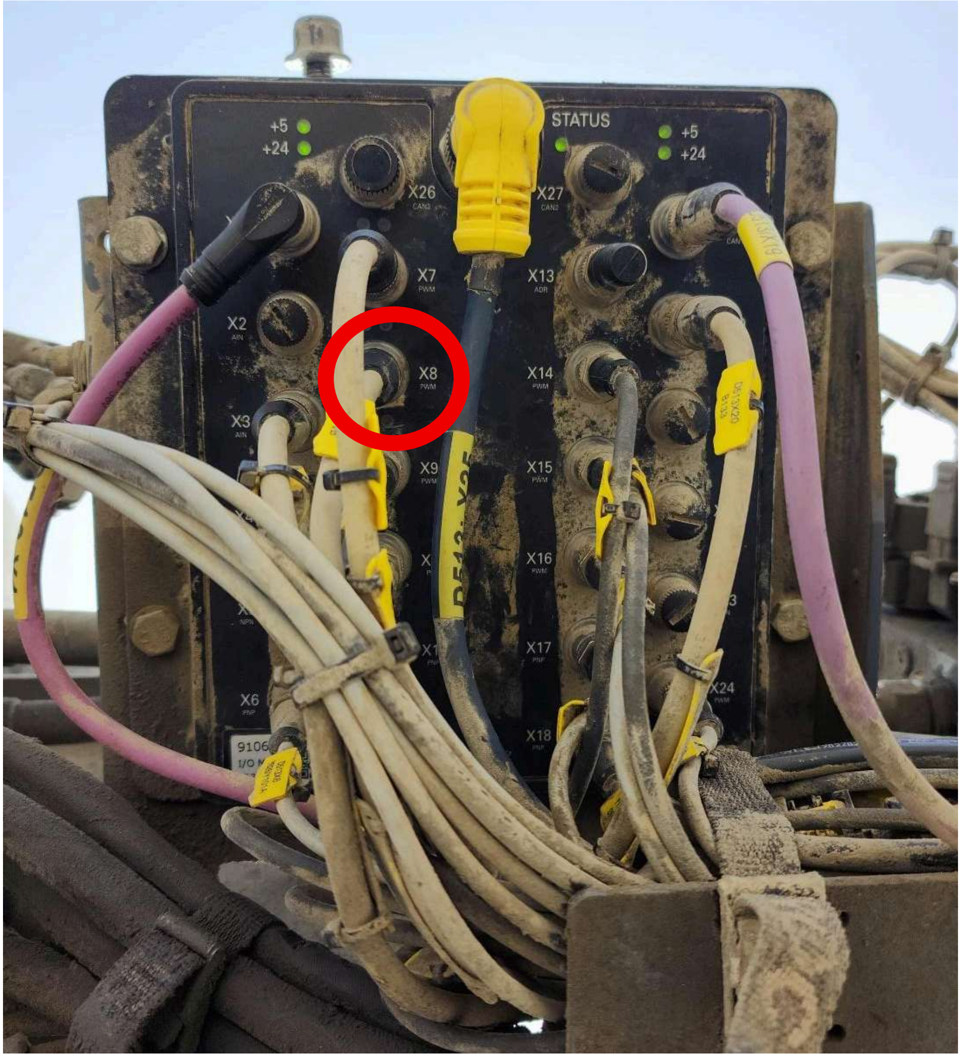
To achieve the auto-stop function on the machine, the system interfaces with the feed-down (or feed-forward) circuit using a normally closed (NC) relay connection. Under normal operating conditions, the electrical signal flows through the circuit uninterrupted, allowing standard machine operation as if the system were not present. Once the Groundworks system identifies that the target design depth has been reached, the output relay is energized and the circuit opens. Consequently, the electrical path to the feed-down mechanism is broken, halting downward movement even if the operator continues to actuate the joystick.

Following the same concept as for the outputs, the electrical manual of the machine will tell where to find this signal, named by Epiroc as “Feed Forward”. In this case, it is located on the electrical module D513, at port X8A, pin 4, according to the screenshot below.



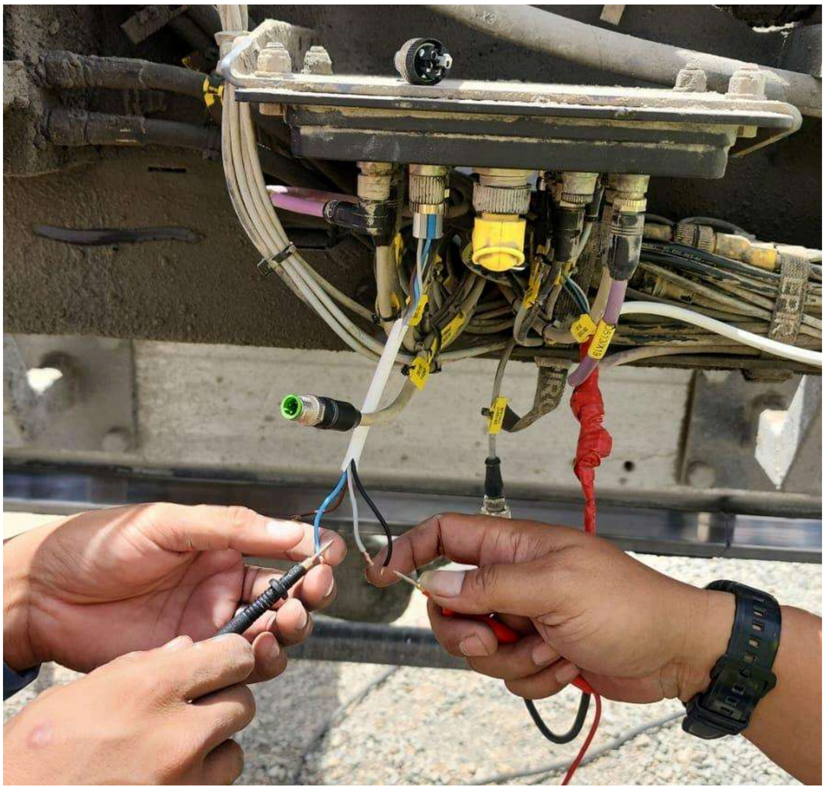
This module is located on the middle of the arm, according to the Epiroc Interface.

Modules
Module Layout
Module Information
CAN Communication OK
Can node id 33
Module state Operational
Memory OK
Module supply 27.0 V
Sensor Supply 24V OK
Sensor Supply 5V OK
Outputs OK
Version 5.5
Article number 6611
Serial Number 6308
Module Temperature 45.0 °C

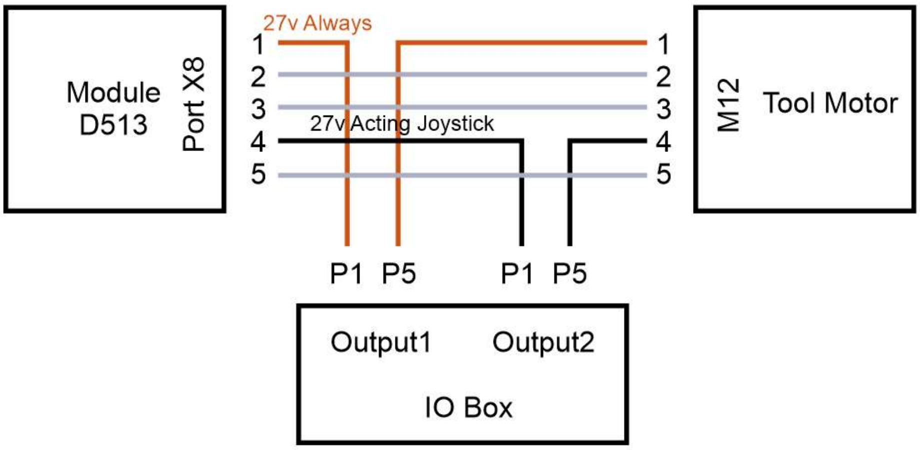


To identify the correct wire on the machine, the procedure begins by disconnecting the control cable from the target port to verify if the operator loses all functionality for the feed-down movement. If all downward movement is successfully disabled, the correct cable harness has been isolated.

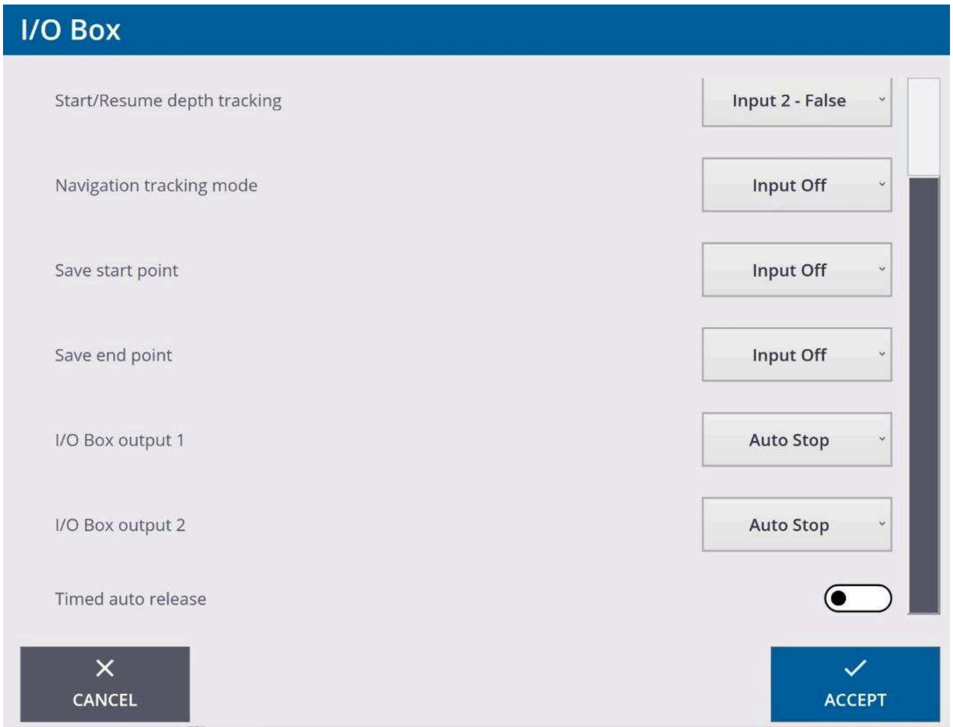
The next step involves identifying which specific conductor within the disconnected harness transmits the activation signal to the feed motor – corresponding to Pin 4 on the electrical schematic. For this test, a standard Groundworks CAN cable with stripped wire leads can be connected to interface with the port. Using a digital multimeter, the negative (black) lead should be secured to an unpainted chassis bolt to establish a reliable frame ground. The positive (red) lead is then used to probe the pins of the X8 port individually while the operator fully actuates the feed-down joystick. This process identifies which pin receives electrical power during the command. Note that while the reference image demonstrates a ground connection taken directly from a known ground wire in the harness, utilizing a clean chassis ground is the preferred field method to ensure measurement accuracy.



On this particular machine, testing indicates that the black conductor registers 27V only when the operator actuates the feed-forward command via the joystick, while the brown conductor maintains a constant 27V potential under all conditions. Both power signals have been spliced to run inline through the system, with each connected to **Pin 1 (Brown)** of a respective output port on the I/O Box, as illustrated in the wiring diagram. All remaining conductors within the original machine harness are left unaltered in their factory configuration. From **Pin 5 (Grey)** of each respective I/O Box connector, a wire extension is routed back to the where the signals where originally connecting. This routing ensures that the control signals pass through uninterrupted when the internal relays are de-energized and are successfully cut when the relays are energized by the system.

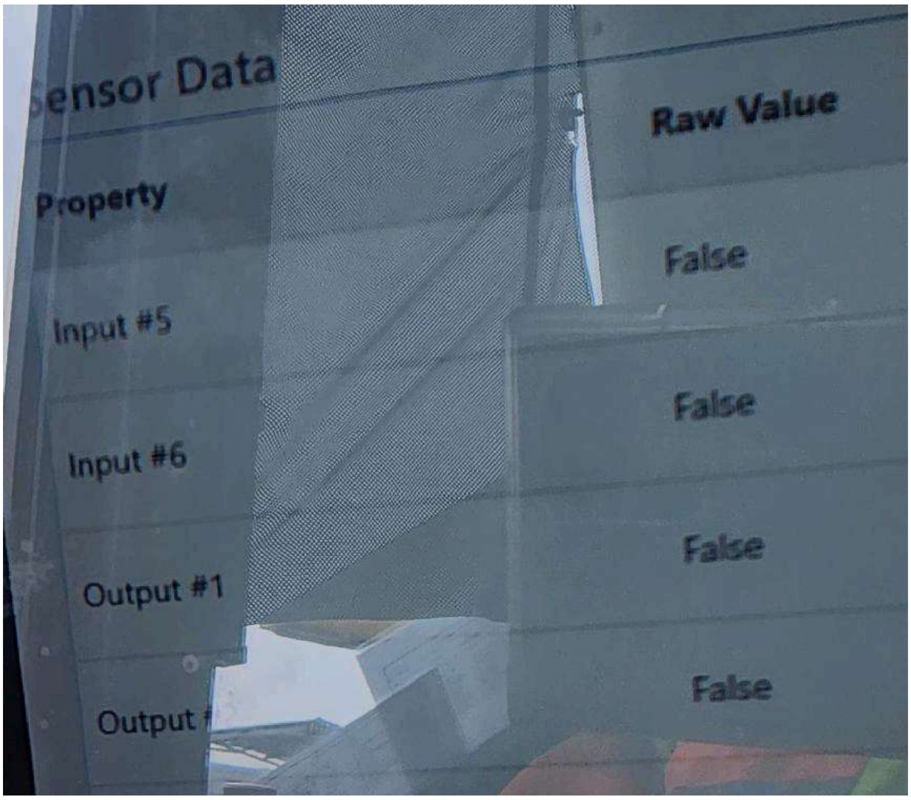


Both outputs are configured for the AUTOSTOP function, ensuring that when the system is triggered, both positive supply circuits open simultaneously. This breaks the electrical path and leaves the feed motor completely isolated from any external power source, simulating a full cable disconnection.



To verify the circuit logic, the Diagnostics toggle function was used to manually force the I/O Box outputs. With both output relays energized, the control signals successfully opened, breaking continuity and entirely disabling the operator's ability to actuate the downward feed. Toggling the outputs back to their inactive state de-energized the relays, instantly restoring factory continuity and returning feed-down control to the operator. This successful manual test validates that the internal relays function correctly and that the target machine circuits have been accurately isolated.

Following this hardware validation, a test borehole was drilled to verify that the automated auto-stop logic executes dynamically during active operation. The objective is to ensure that the system fires the override command precisely when the live depth calculation meets the target design depth of the active production hole. Real-time signal transmission can be monitored via the software's diagnostics page, where the digital state of the corresponding outputs will visually transition from TRUE to FALSE upon reaching the target elevation.



Conclusion

Implementing an automated depth tracking and guidance system on a drilling rig delivers immediate, high-value returns for project managers and fleet owners. By automatically distinguishing between actual drilling and the necessary mechanical movements of changing rods, the system ensures the absolute reliability of your production records. For the customer, this means guesswork is completely eliminated; you receive a highly accurate, indisputable, and automated log of the exact drilled depth for every single hole on the job site.

Beyond precise record-keeping, the system acts as a built-in quality control supervisor through its "auto-stop" feature. By instantly halting downward progress the exact moment the drill bit reaches the engineered target depth, it completely prevents accidental over-drilling. This directly protects your bottom line by eliminating the wasted time, unnecessary fuel consumption, and excessive tool wear caused by drilling deeper than the project requires.

Importantly, this strict quality control does not restrict your team's agility in the field. If unexpected ground conditions require drilling past the planned depth, the operator can bypass the restriction in seconds. By simply lifting the drill tool upward by 25 centimeters, the system resets, opens the safety lock, and restores full manual control to the operator. Ultimately, this integration provides customers with the ultimate combination of automated efficiency, strict quality assurance, and seamless on-site flexibility.